Main Injector Beam Position Monitor Upgrade: Status and Plans

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Project Overview

- Goals:
  - Improved reliability (hardware and software).
  - Improved position resolution.
  - Measure beam bunched at either 2.5 or at 53 MHz.
    - Allows measurement of anti-protons. New capability in MI.
  - Must be highly configurable; separate configurations for each type of “MI cycle”. New capability in MI.
- Joint AD/CD Project.
- Core technology:
  - Commercial digital receiver board (Echotek).
  - Standard: RR, TeV, transfer line and MI BPMs.
- Overall design: evolution of the TeV BPM design.

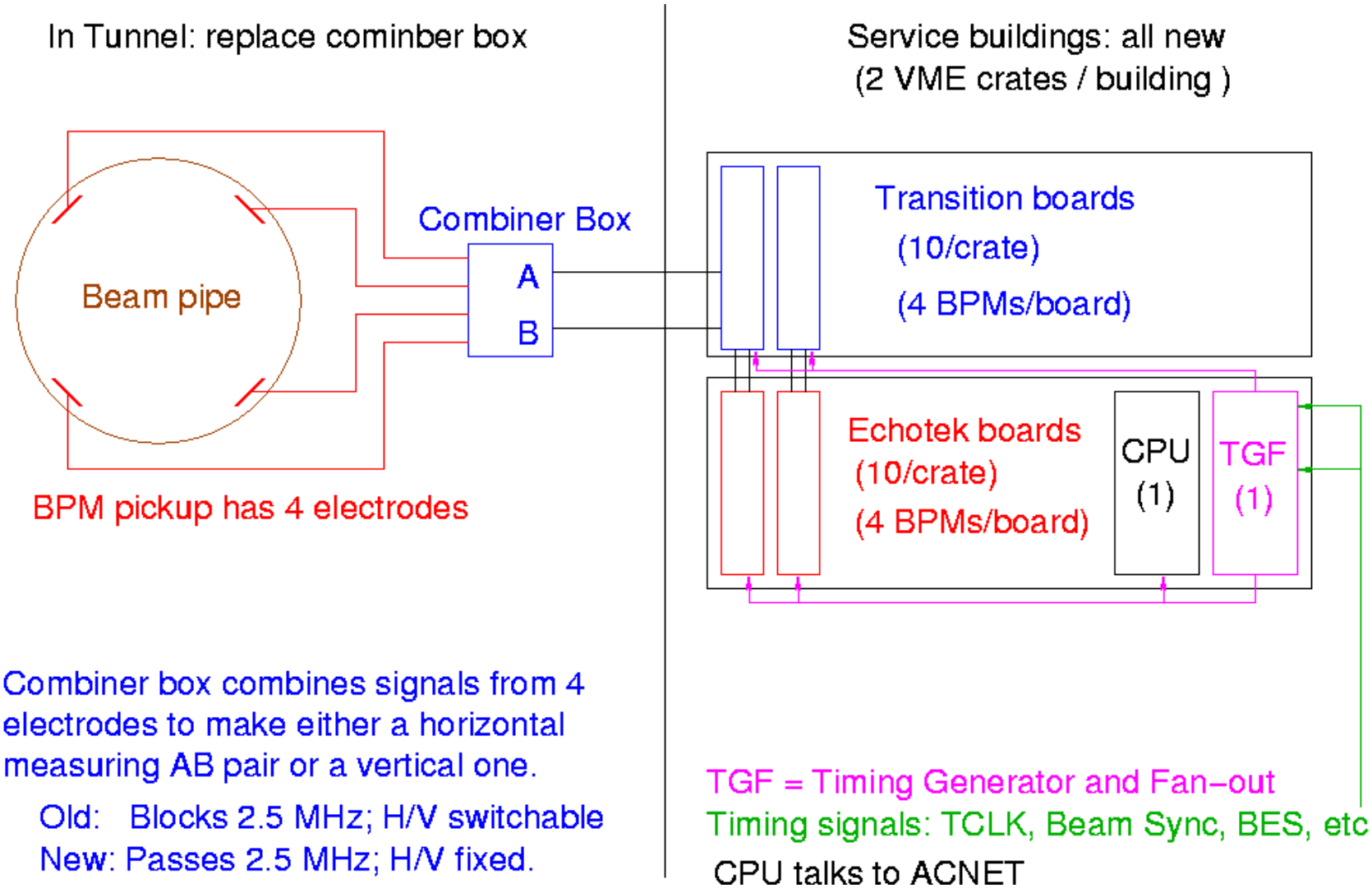
Major Modes

- Closed orbit (CO):
  - Average over all bunches for ~40 turns.
  - Averages out betatron motion (not synchrotron motion; by design).
- Turn by Turn (TxT):
  - Average position over ~44 buckets (~1/13 of circumference).
  - Usually triggered by injection/extraction TCLK events.
  - Can be hand triggered at an arbitrary time, eg pinger.
- Safe mode:
  - Average position over ~44 buckets.
  - Report updated position every ~22 buckets.
  - Continuous for about ~470 turns.
  - Useful when detailed timing is unknown.
- CO and TxT: implemented for both 2.5 MHz and 53 MHz.

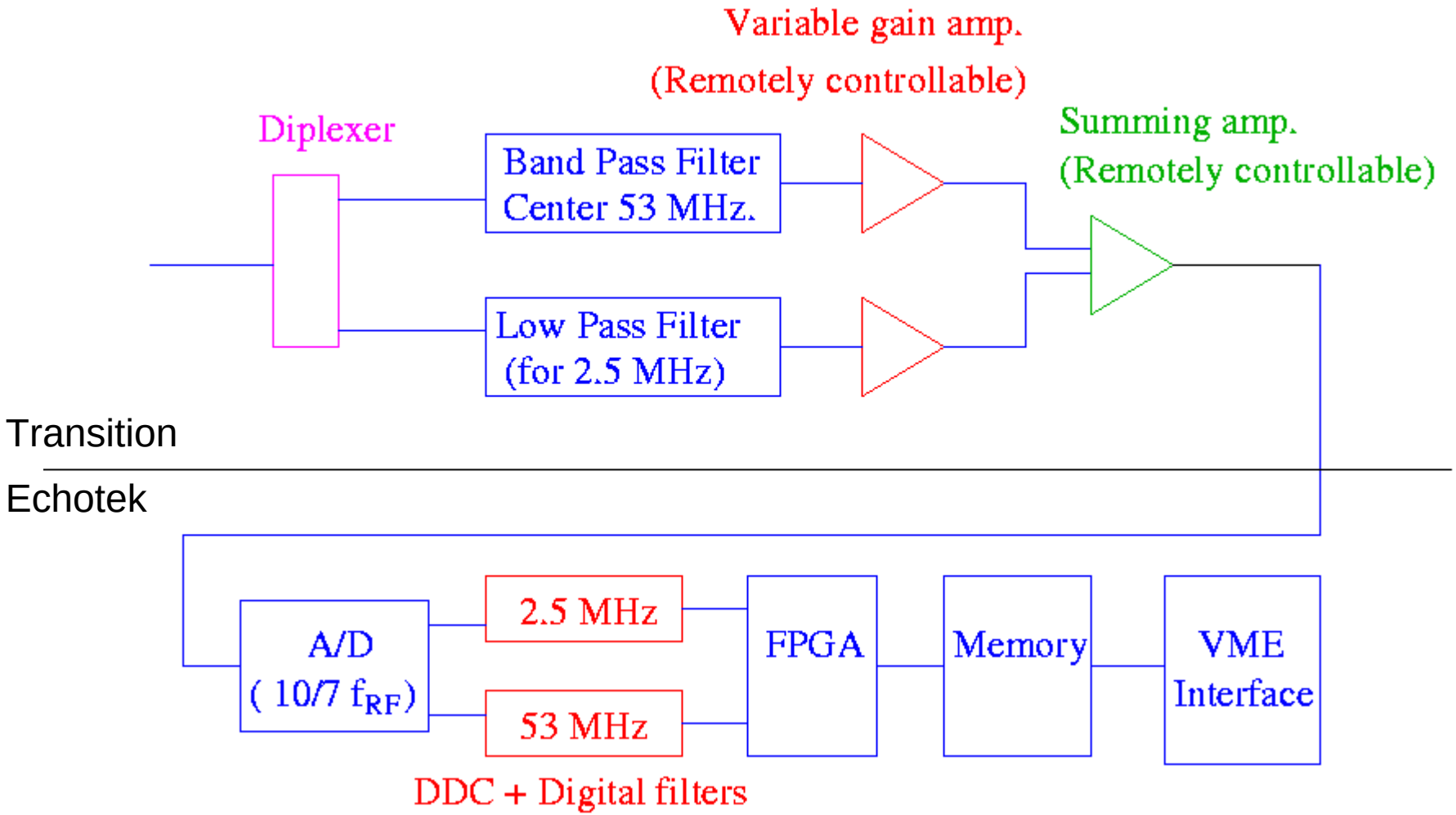
Operational Complexity

- Sources of beam:
  - Booster; Accumulator; Recycler; Tevatron (tuneup).
- Destinations for beam:
  - Tevatron; Recycler; Anti-proton production target; NUMI target; Switchyard 120; Abort dump; Accumulator (tuneup).
  - Multiple destinations allowed on a single cycle.
- Injection/extraction lines all at different locations.
  - May transfer either protons or anti-protons (at different times).
- Many tens of possible “MI cycles”:
  - Inject beam (once or many times).
  - Ramp to new energy; slip position; change RF structure.
  - Send beam to destination(s).
- MI “plays” a long sequence of interleaved cycles.
- Detailed TxT timing is different for each cycle.

Cartoon of the Hardware



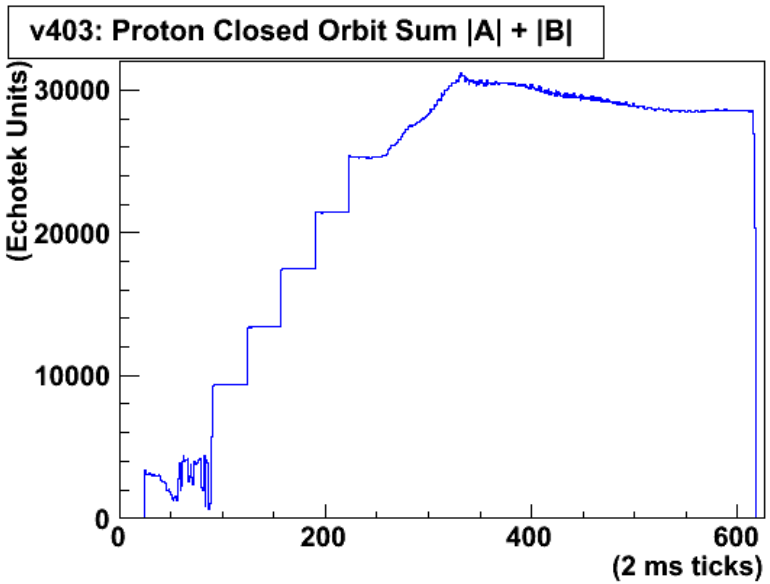
Cartoon of Transition and Echotek Boards

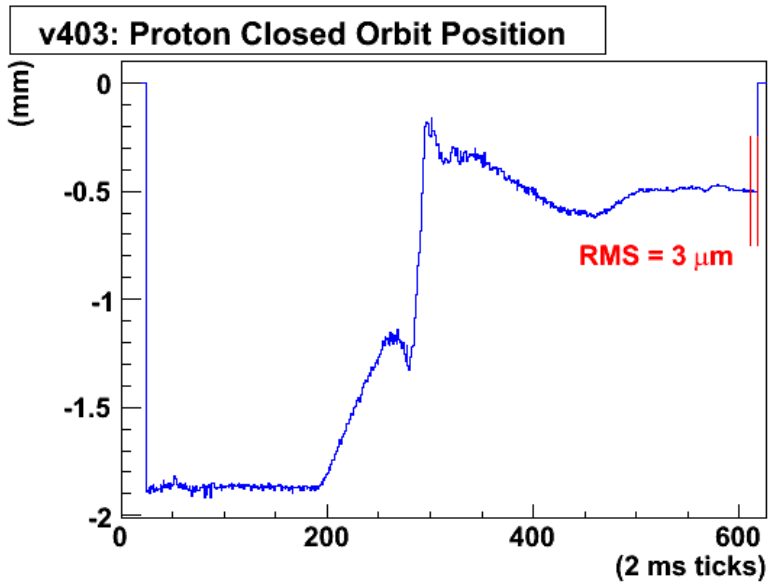


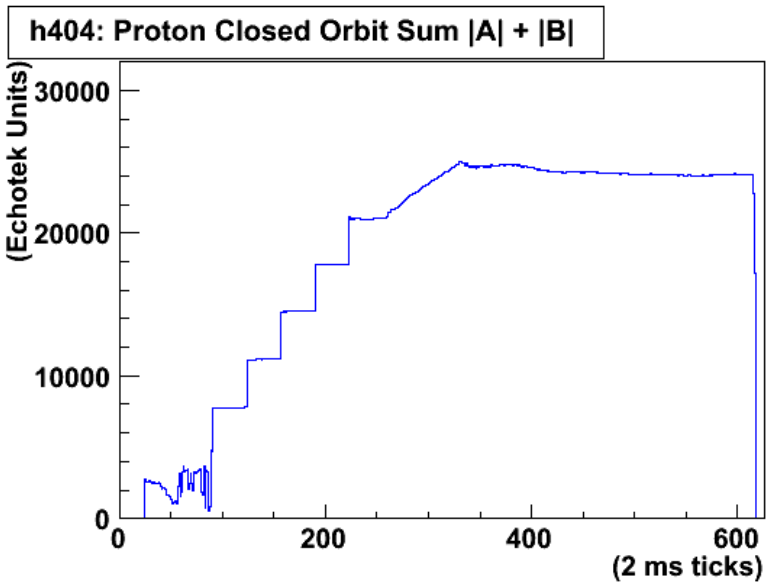
Notes on Cartoon Figures

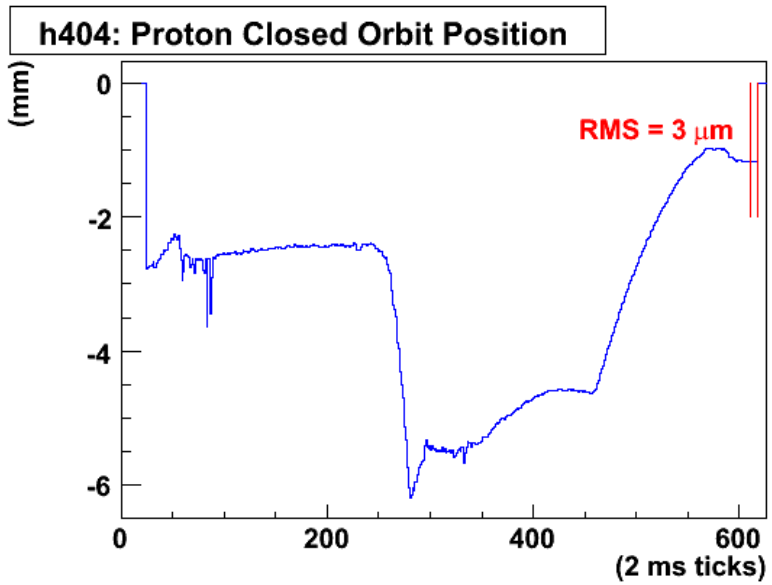
- TGF, Combiner and Transition boards: in-house designs.
- Combiner board:
  - Old boxes contained a band pass filter to select only the 53 MHz component:
    - Anti-protons are usually bunched at 2.5 MHz so the old system was blind to anti-protons (most of the time).
    - New system allows both 53 MHz and 2.5 MHz components to pass. Can see anti-protons now.
  - Old system was H/V switchable:
    - Rarely used.
    - Now fixed H or V. Reduces points of failure by removing unnecessary complexity.
- Transition Board:
  - Two bass bands: 53 MHz and 2.5 MHz.
  - Gain in each band separately controllable.
  - Output can be one, other or sum.

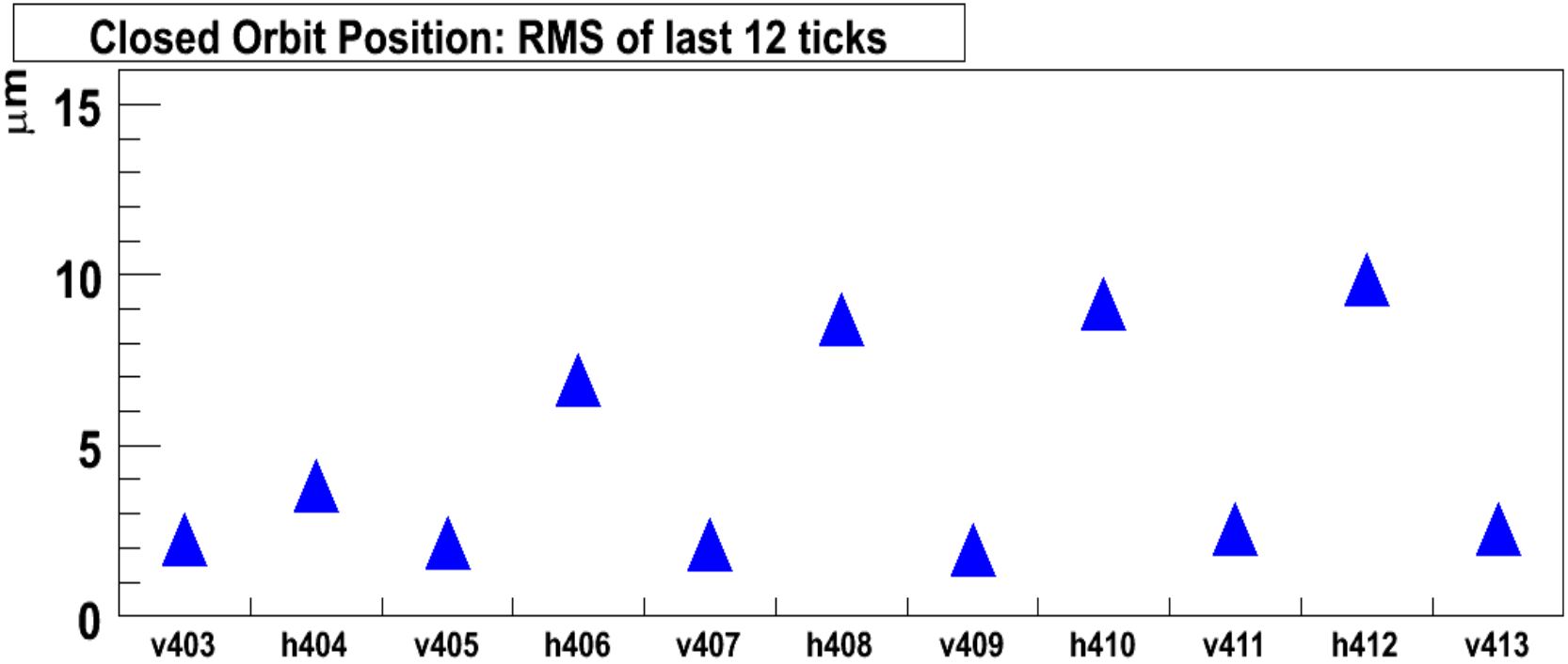
Proton Beam: Anti-proton Production + NUMI



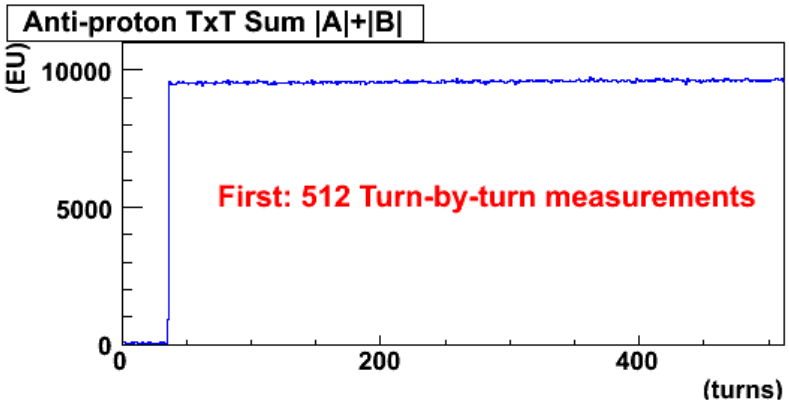


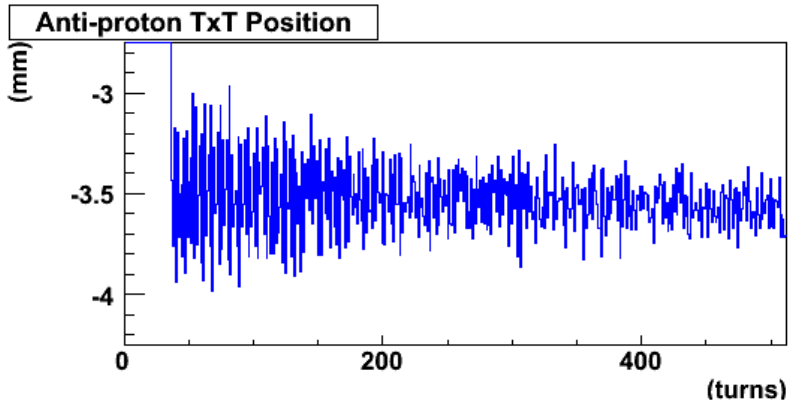


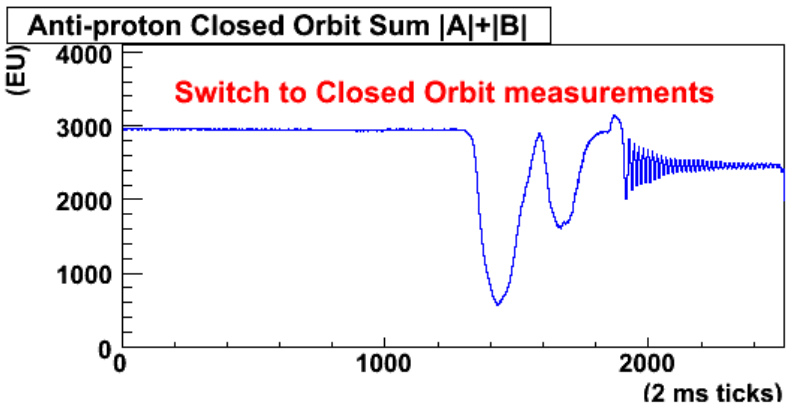


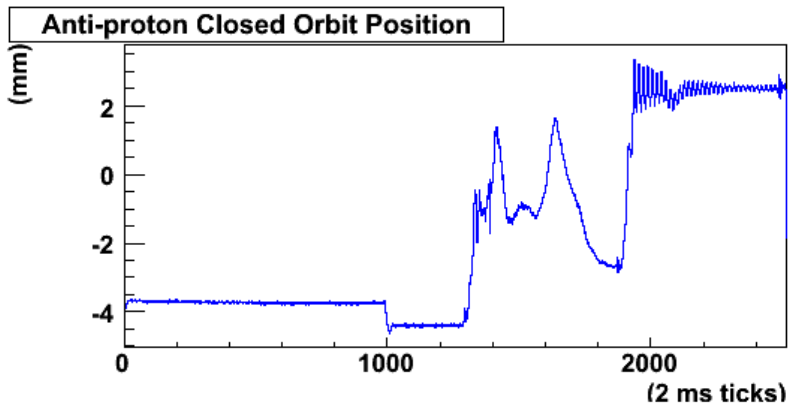


- Observed RMS includes resolution of the instrument plus real beam motion.
  - Almost certainly dominated by real beam motion, especially for the horizontal BPMs.
- Meets required closed orbit position resolution of 50 μm (3σ).



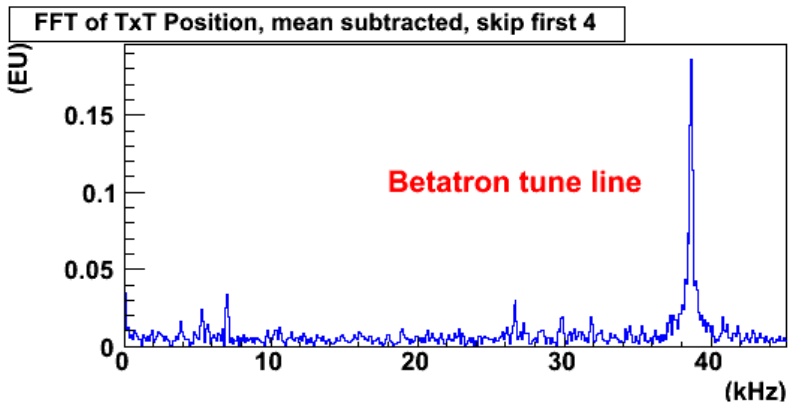






Transfer of anti-protons from accumulator to Recycler.

(Mode switch on the fly!)



Looking Ahead

- April 2006:
  - Receive production transition boards and crate backplanes.
  - Most other components in hand.
  - Assemble and test complete crates in the lab.
- Late May 2006:
  - Restart MI using the BPM system as it existed at shutdown:
    - 11 upgraded BPMs, remainder old.
  - Continue commissioning of existing house during this time.
- Once operations have been re-established (mid June?), install remaining BPMs.
  - Details of timing to be negotiated with MI operations and MI BLM upgrade project.
  - Can be performed while MI is operation.
- Completion goal: summer 2006.
- Anticipated effort: 7 to 10 FTEs / month.

Summary and Conclusions

- Design is complete and well tested.
- Commissioning of first house advanced.
  - Will be completed during the restart phase.
- Will be ready to install all new hardware before the restart.
  - Last components (transition boards) due during shutdown.
- Expect to complete installation and commissioning within a month of getting the go ahead.

Backup Slides

Cycle Dependent Configuration

- MI State 5:
  - Two batches from booster. Slip stack to form one batch.
  - Five more batches from booster.
  - Ramp to extraction energy.
  - Deliver slip stacked batch to anti-proton production target.
  - Deliver 5 remaining batches to NUMI.
  - Repeat about every 2 seconds (may interleave with other cycles).
- BPM Configuration:
  - For each of 7 injections, measure the leading half of the newly injected batch, TxT by turn for 512 turns.
  - After last injection, make CO measurements; report at 500 Hz.
  - Just before extraction change back to TxT mode and measure the last few turns before one of the extractions.
    - Not enough time between extractions to reconfigure the system to get both.
  - Store all information until the next instance of state 5.

Timeline to Date

- December 2004 – first organizational meetings.
- Summer 2005 – Project started.
- December 2005 – First measurements using prototype transition and TGF boards.
- February 2006 – One “house” (11 BPMS) instrumented using preproduction transition boards and production TGF.
  - Used operationally for about 1 week before shutdown.
- All major capabilities have been demonstrated at least once.
  - Many capabilities have been routinely used for about 2 weeks.
  - Commissioning of the first house is nearing completion.
- Effort: typically 7 to 10 FTEs / month